REDUCTION OF PG1115+080 IMAGES

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1. THE DATA

The data are three exposures in PC6 through F785LP obtained on March 3, 1991. The exposure times are 120, 400, and 400 seconds. The data are reduced with the "standard" WFPC reduction scheme: A-to-D correction, DC bias subtraction, AC bias subtraction, dark current subtraction, preflash subtraction, and flat field normalization, using the best available calibration data. The exposures are combined into a weighted average normalized to 400 seconds exposure time, so one DN (data number) is about 17.25 electrons. At this step, cosmic rays are removed by intercomparison of the three images.

2. THE GOAL

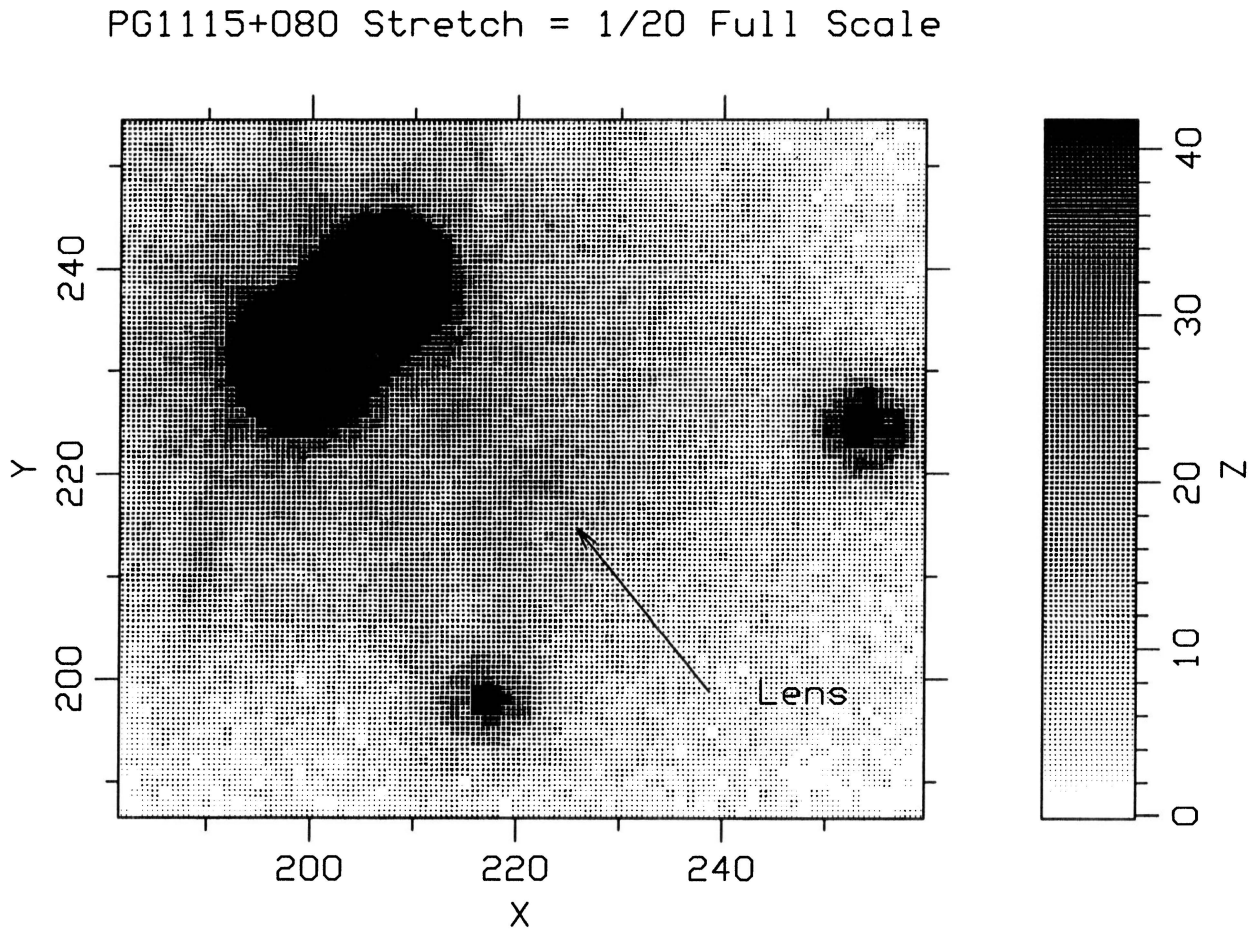
The lensing object can be seen in the processed image. One would like to subtract the four QSO images to leave behind a clear picture of the lens.

3. THE PROBLEM

Due to various glitches there is no high signal-to-noise PSF observation contemporaneous with the PG1115+080 observations. Since the data were obtained, the secondary mirror has been moved several times in an attempt to improve the performance of the FGSs, so it is unlikely that a PSF suitable for subtraction will *ever* be obtained.

4. THINGS THAT DON'T WORK: A "THEORETICAL" PSF

One of the things we tried was a PSF from the STScI library of PSFs. The library



contains PSFs calculated "from first principles." While the library PSFs are qualitatively similar to the actual PSFs—one can make correspondences between the tendrils and rings, etc.—the library and actual PSFs differ in quantitative details which are important for the kind of subtractions required here.

The subtractions of the library PSF yields an image in which the lens is obscured by incomplete removal of the outer parts of the PSF. We attempted to calculate more accurate PSFs but were not successful.

5. THINGS THAT DON'T WORK: A LOW S/N PSF

Observations of Q0957+561 were obtained the same day as those of PG1115+080. One of the QSO images in these exposures is sufficiently well separated from the lens and the other image that it can be used as a PSF. Unfortunately, one of the two exposures with F785LP was badly jittered, leaving only a single 350 second exposure to be used for the PSF. Although the core of the PSF is well exposed, the halo is not. Using this object for subtraction introduces so much noise in the resulting image that the lens is obliterated.

6. SOMETHING THAT WORKS: AP LIB (BUT IT'S HARD)

Observations of AP Lib were obtained the same day as those of PG1115+080. These

observations include three exposures through F785LP in PC6. The exposure times are 30, 500, and 500 seconds. These data were processed through the standard reduction in the same way as the PG1115+080 observations. In this case, the combination of the images into a weighted average also takes account of the fact that the central four pixels of the 500 second exposures are saturated and uses only the data from the 30 second exposure for these pixels.

An advantage of the AP Lib exposure is that it's very high signal-to-noise: a saturated core means that the halo is well exposed. Another advantage is that AP Lib is centered on PC6 only about 55 pixels from the center of the PG1115+080 images.

A big disadvantage is that AP Lib is not a point source: there is a galaxy underneath that fills the entire detector!

However, it appears that AP Lib can be well approximated as a point source plus a concentric, circularly symmetric galaxy. It should be possible to take advantage of this symmetry.

7. ASSUMPTIONS AND PROCEDURES

Assume that the AP Lib image is a circularly symmetric smooth galaxy concentric with a point source manifested as the PSF. Note that this assumption is probably not quite correct. The convolution of the PSF with a smooth function should give back a smooth function. But, at the center, the galaxy in AP Lib may have structure on scales comparable to the structure in the PSF. Thus, the validity of this assumption must be judged by how well the procedure works.

In any case, with this assumption, the model is that everything in the PG1115+080 image with the exception of the lens can be represented as:

$$s(\mathbf{r}_j) = \sum_i a_i \left(A(\mathbf{r}_j - \mathbf{r}_i) - G(|\mathbf{r}_j - \mathbf{r}_i|) \right)$$

where $s(\mathbf{r}_j)$ is the signal in pixel $\mathbf{r}_j$, $\mathbf{r}_i$ is the center of QSO image $i, i = 1, 2, 3, 4$, a_i is the relative strength of QSO image i, A is the AP Lib image, and G is the circularly symmetric galaxy profile in the AP Lib image.

This model is fit to the PG1115+080 image using weighted least squares. The AP Lib image is translated to each QSO position with bi-cubic interpolation. The galaxy profile, G, is represented as 101 numbers giving the value of the profile at radii from 0 to 100 pixels; linear interpolation is used to center G at each QSO image. Altogether there are 105 parameters estimated by the fit: four QSO amplitudes and 101 numbers in the profile. Errors are determined by propagation of errors using the read and photon noise in the PG1115+080 image. The fit is performed for three cases: In case 1, a patch of 12 pixel radius centered on the lens is excluded from the fit. In case 2, the lens is not excluded, case 3 is a fit to a simulation, whose description is omitted due to space considerations. The following table summarizes results from the fits:

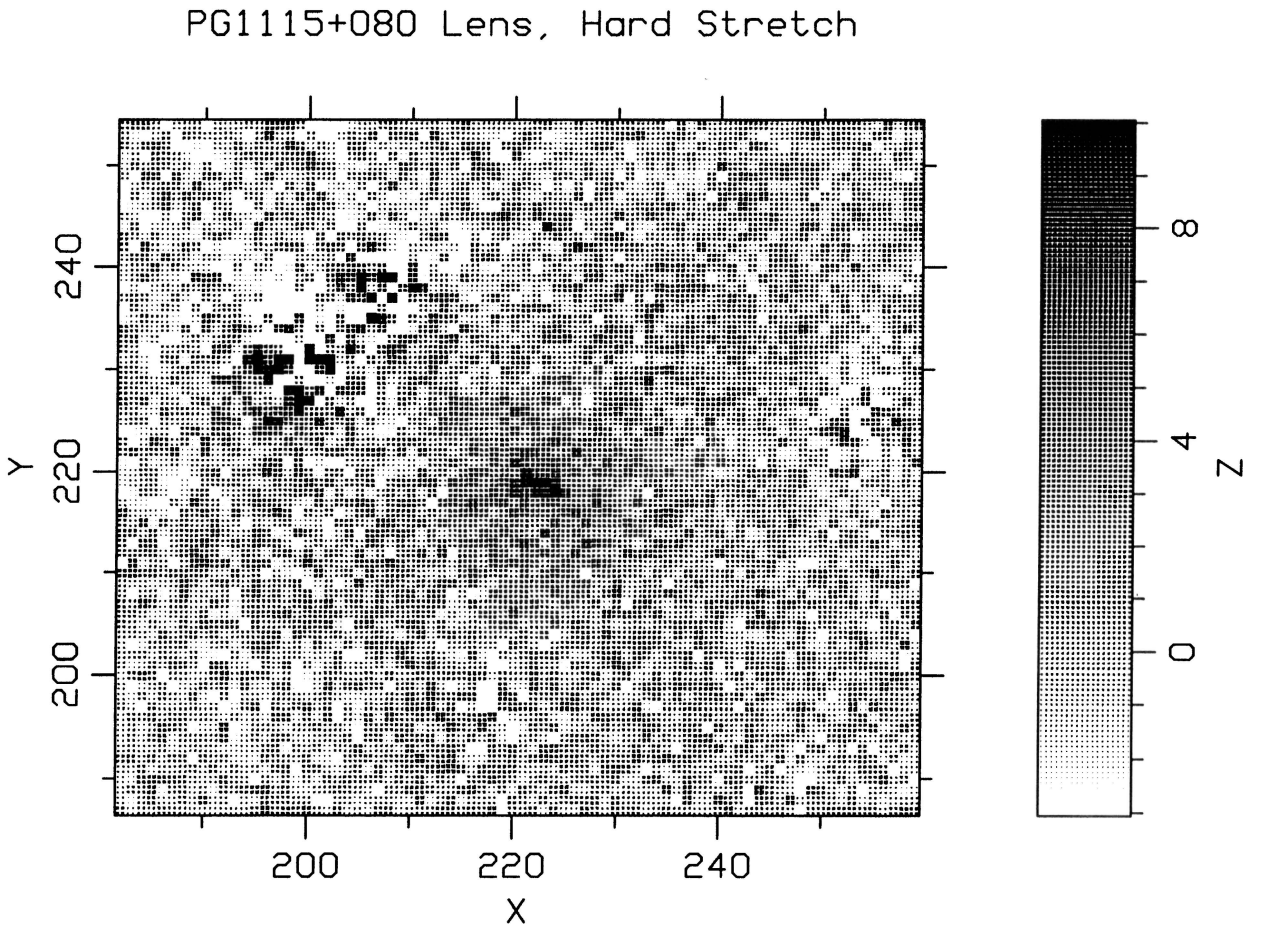
Case	Pixels in Fit	Degrees of Freedom	χ^2 Before	χ^2 After
1. Lens Excluded	46180	46075	815738	48772
2. Lens Included	46621	46516	861359	50097
3. Simulation	46180	46075	832000	47856

and the following shows the QSO parameters

QSO	a_i (Case 1)	a_i (Case 3)	Case 1 Rescaled
A1	0.1180 ± 0.0017	0.1159 ± 0.0013	0.1150
A2	0.0819 ± 0.0012	0.0795 ± 0.0009	0.0798
B	0.0204 ± 0.0003	0.0199 ± 0.0003	0.0199
C	0.0315 ± 0.0005	0.0301 ± 0.0004	0.0307

8. RESULTS OF THE SUBTRACTION

Once the QSO amplitudes, a_i, and the galaxy profile, G, are determined, the QSOs can be subtracted, leaving a picture that contains only the lens (and possibly the fifth image!). The results shown are for case 1, the lens excluded fit. The results for case 2, the lens included fit, are similar, except that the galaxy profile is a little higher at radii corresponding to the distance of the lens from the two brighter QSO images. The subtraction then leaves the lens slightly fainter and leaves a slight hole to the upper left of the two brighter QSO images at about the same distance as the lens.



9. FUTURE WORK

Future work will attempt to improve the subtraction, to deconvolve the lens, and then to improve the lens model based on these data. Additional observations will be proposed in order to obtain a higher signal-to-noise image of the lens.